DESIGN FOR POWER PLANT

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ARMOUR INSTITUTE OF TECHNOLOGY

1910

DESIGN

FOR

POWER PLANT

A THESIS

PRESENTED BY

PROCTOR E. HENWOOD

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

MAY 20, 1910.

[illegible]

H M Raymond
Dean Engineering

[illegible]

SCOPE OF THIS THESIS.

A corporation in the City of Chicago has at present two buildings located within the loop district. One of these buildings is devoted to office use; the other to light manufacturing and jobbing concerns. It is proposed that a new building will be erected to be devoted to manufacturing purposes, its location being on the Chicago River. See Map. The power for lighting and operating the elevators in the two buildings mentioned is purchased from a central station. A low pressure steam heating system furnishes heat for both buildings.

The economical questions are: First, will it pay to operate the three buildings as one unit, i.e., with a plant located in the new building; Second, what will be the cost of such a plant; Third, the probable revenue to be derived; and Fourth, the cost of operation.

Operation of three buildings as one unit.

Under the present method of operation the following help is employed: A Chief Engineer, one Assistant Engineer and two fremen; this is for the winter months. Through the summer months when the heating system is not in use the firemen can be dispensed with, as the Assistant Engineer can tend the hot water fire during the day and the night watchman at night. With one large plant the above help increased by one assistant engineer, one fireman and one oiler, is ample for operation at all times. Also owing to the fact that all labor and fuel are at one point, operation will be cheaper than with two smaller plants. As the plant would be near the river it can be operated condensing with high economy through the summer months. The tunnel of the Illinois Tunnel Company to the other building affords an easy means for transmission of steam and electric current.

Description of Plant.

The plant consists of water tube boilers fed by chain grate stokers, overhead coal bunkers, and coal and ash handling machinery. High speed compound engines running condensing direct connected to direct current generators. Coal will be delivered through the tunnel or by wagons direct to storage bin without extra handling.

Estimated Cost of Plant.

The plant is estimated to cost $60,000. of which amount $46,000. is required for the electric plant and $4,000. for heating.

Estimated Annual Gross Revenue.

It is expected that all light and motive power required by the tenants will be furnished by this plant. The estimated amount of current from which a revenue can be derived is 420,000 kilowatt hours. Computing this at a metered rate of 10¢ per kilowatt hour, with a rebate of 1¢ per kilowatt hour for prompt payment, i.e., 9¢ gives $37,800. This price of 9¢ per kilowatt is the rate at which the Commonwealth Edison Co. furnishes current for individual lighting.

Estimated Cost to Operate Plant.

Interest 4.5%, Depreciation 5% insurance and taxes 2% = 11-1/2% on $60,000.		$6,900.00
Fuel -		
845,000 KW hrs. @ 8# - - -	3380 tons	
Standby losses 1-1/2 tons per day	548	
	3928 "	
3928 tons @ $1.50 + .50 = - - - - - -		7,856.00
Labor -		
1 Chief Engineer	$150.00 per mo.	
2 Asst. Engineers @ $85.00	170.00	
1 Oiler	70.00	
3 Firemen @ $75.00	225.00	
1 Helper for Bldgs. "A" & "B"	75.00	
	690.00 per month	
Labor for 12 months - - - - - - - - - -		8,280.00
Hauling ashes - - - - - - - - - - - - -		300.00
Machinery Repairs - - - - - - - - - - -		350.00
Supplies, packing, oil and waste - - - - - -		400.00
Tunnel Rental - - - - - - - - - - - - -		2,000.00
		26,086.00

Revenue.

The estimated revenue will be as follows:

Estimated Gross Revenue: (See page 28) 420,000 KW Hrs. @ 9¢ per KW hr.	37,800.00
Estimated Net Revenue - - - - - - - - - -	11,714.00

Investment in plant other than that required for heating = $60,000. - $14,000. = $46,000.

Return on investment of $46,000. = 25%

D E T A I L E D   E X H I B I T .

- - o - -

The following pages contain a more detailed Exhibit.

Respectfully submitted ,

Proctor E. Howard

Design of a Power Plant.

With the location given the design of a power plant can be divided into two general parts: first the requirements, and second the design of the apparatus to meet the requirements.

The requirements of a power plant are,- that it shall furnish at all times a stated amount of power in some form as light, heat or refrigeration, or that it can furnish power direct as electric current for conversion, for either individual or commercial use.

The design of a power plant in general depends upon the form of energy desired. Individually the design is broad and variable, being influenced by many factors, such as accessibility to fuels, kinds of fuel and their costs, availability of water supply and its purity. The most important factor is the load,for upon this the efficiency of the plant is based. When the load is constant and at full rating the highest efficiency can be obtained, but with a variable load and at low rating the efficiency falls off and operation becomes costly.

The plant under consideration has been designed to meet the requirements of typical office and light manufacturing buildings, and will furnish light, heat and power. Owing to the location of this plant it is expected that power can be sold, and to this end reserve power has been installed.

The plant will operate condensing during the summer months, while in the winter the exhaust steam will be used for heating the buildings. All power necessary for operating elevators and such appliances as the buildings may contain will be furnished by this plant. Also itis in ended to furnish the lighting and motor power to the tenants of the buildings.

The power generators willbe four High Speed Engines direct, connected to direct current generators, as follows:

Unit # 1
75 H.P. Simple with 50 K W Generator
Unit #2
150 H.P. Compound with 100 K W Generator
Units #3 and #4
225 H. P. Compound with 150 K W Generator

A condenser of the surface type will be used in conjunction with Unit #2, #3 or #4.

Four boilers will be installed in batteries of two boilers each, they will be water tube type, fed by chain grates, each boiler being 250 H.P. to contain 2500 sq. ft. of heating surface and operate a steam pressure of 160# per square inch. The grates will have an

area of 63 sq. ft., being 9 feet long by 7 feet wide.

The furnace has been designed for a low grade Illinois coal "Springfield District" and with the large tile roof will insure smokeless combustion. In the floor of the combustion chamber is a small opening that connects with the ash hopper and affords an easy method of removing the light ashes. Sufficient room has been allowed in front of the boilers for removal of tubes and stoking grates in case of repairs. Each battery of boilers enclosed a building column, but at a distance sufficient to allow for an air space around the column. The piping has been arranged with the view of being easy of access, runways being provided over the boilers and along the steam header.

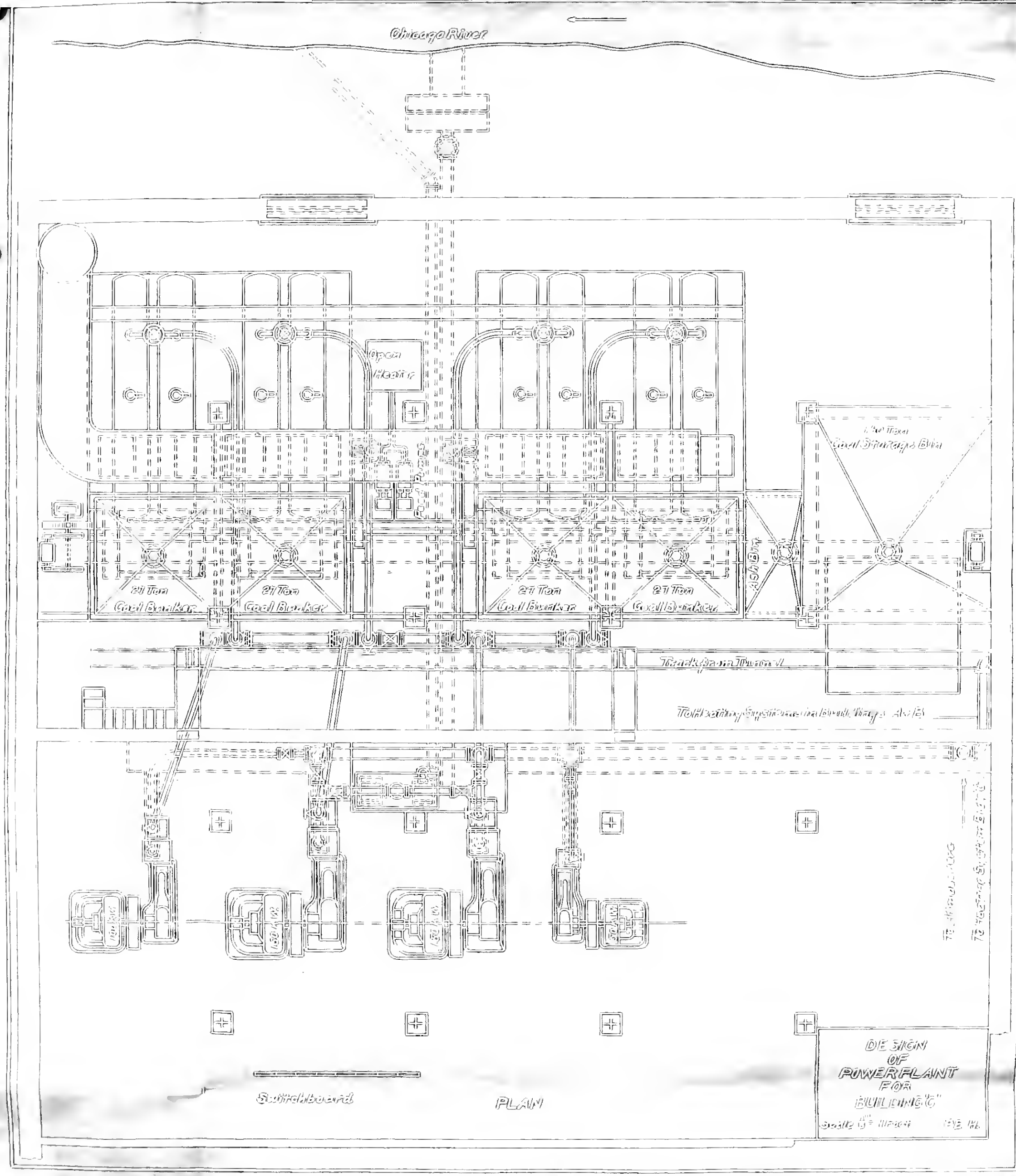
Provision has been made for the delivery of coal by wagons or through the Illinois Tunnel, the floor of the boiler room being at the tunnel grade.

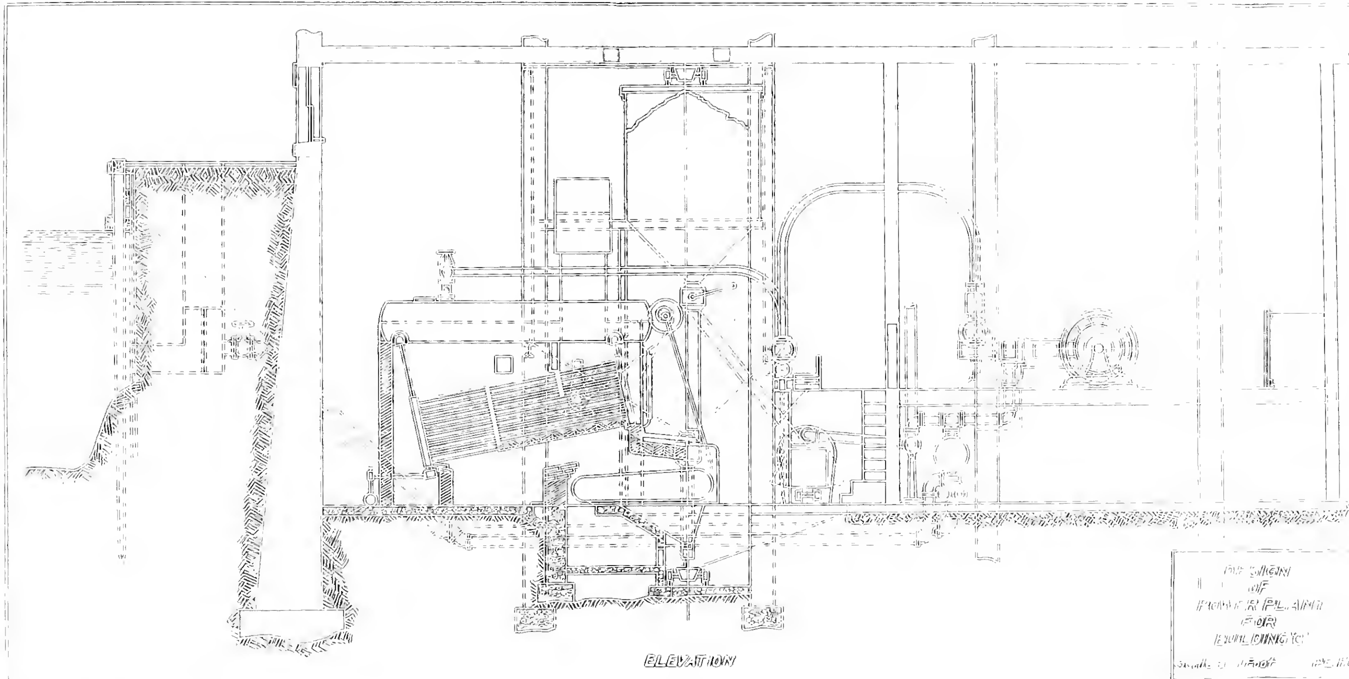
Coal received by the tunnel may be delivered in front of the boilers for hand firing, or dumped into a hopper from which a bucket conveyer will carry it either to overhead bunkers or to the storage bin. Coal received by wagons will be dumped directly into the storage bin, from where it will be fed into the bucket conveyer, thence to bunkers, or by hand carts to the front of the boilers. The ashes will be elevated to the ash bin from which it may be drawn off into the tunnel cars or into a push cart, and taken by an elevator to the surface.

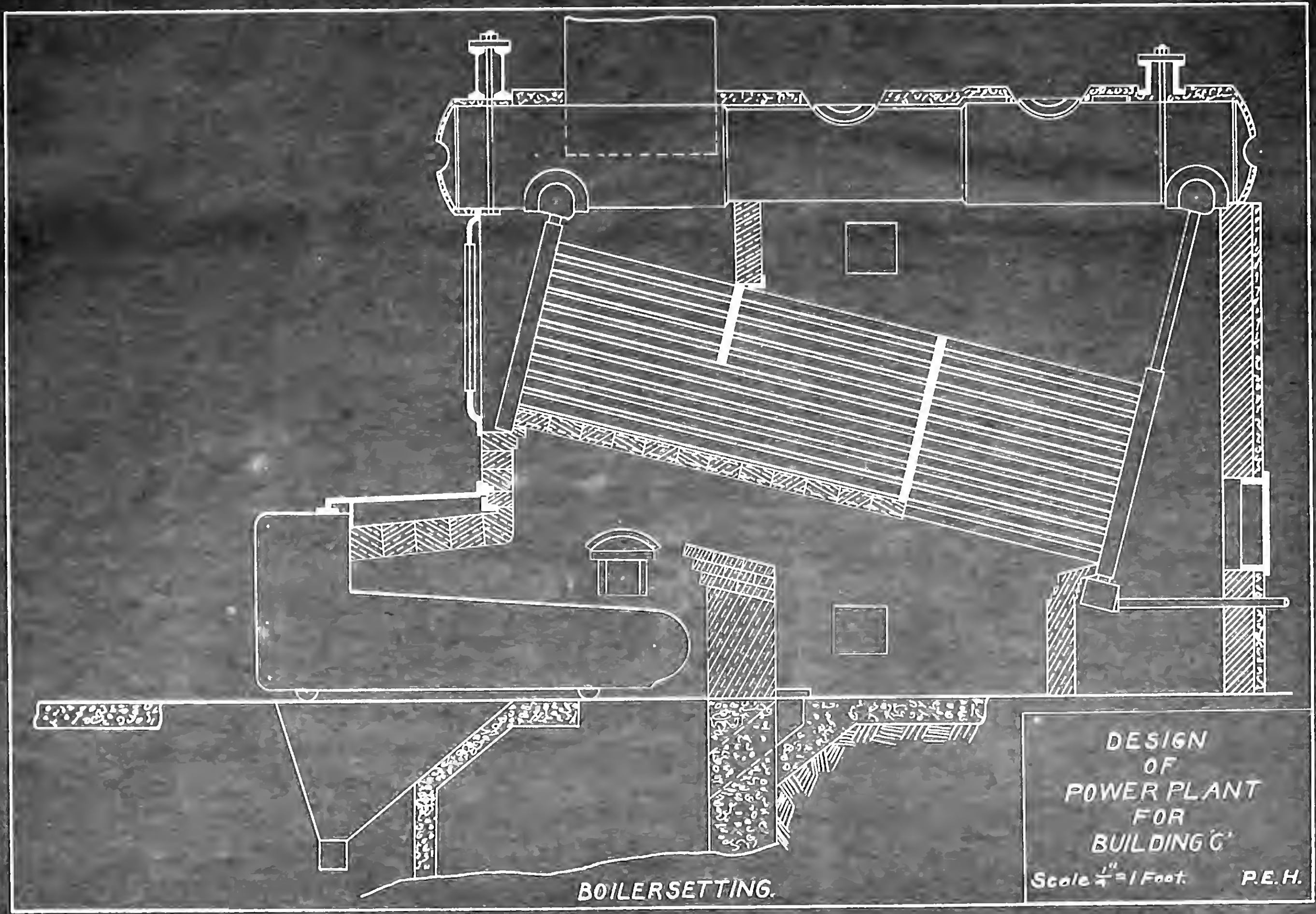
Water from the heating systems in Buildings "A" and "B" will be returned to the plant by means of a centrifugal pump direct, connected to a D. C. motor. The pump will be located at about tunnel grade in Building "A" with its suction attached to a tank conveniently located.

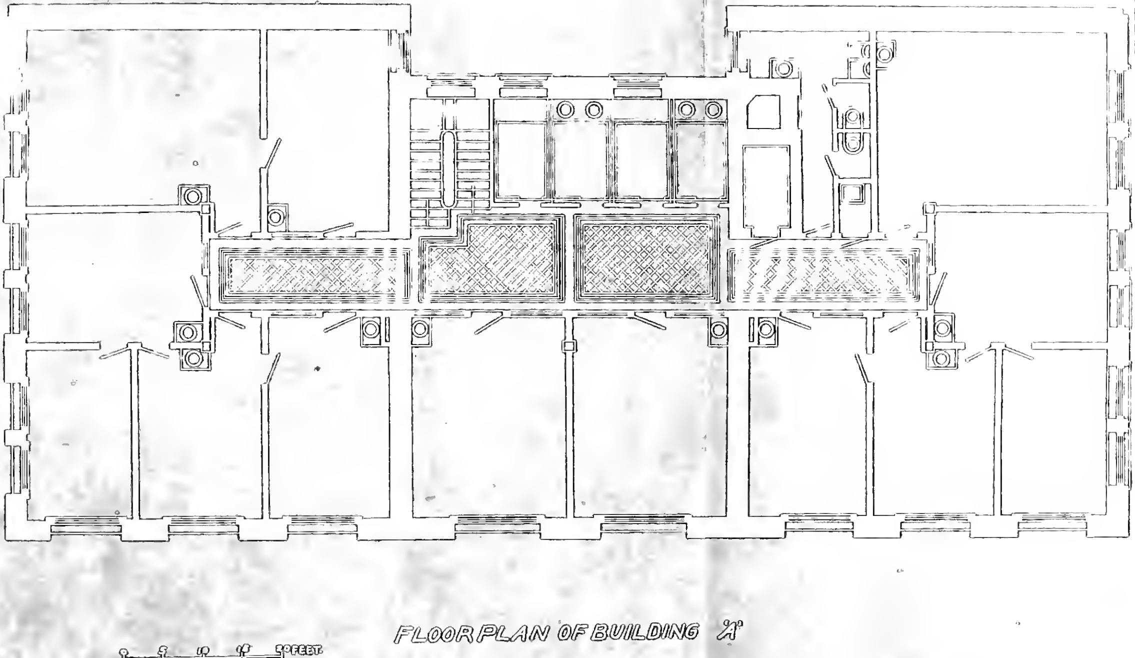
Two duplex boilers feed pumps of the ram pattern are to be installed, the dimensions being 7-1/2" x 5" x 6".

An open type of feed water heater will be used, the exhaust steam from the boiler feed pumps, the condenser pump and the stoker engines being used for heating.


Chicago River
Open Heater
27 Ton Coal Bunker
27 Ton Coal Bunker
27 Ton Coal Bunker
27 Ton Coal Bunker
Ash Bin
Switchboard
PLAN
DESIGN OF POWERPLANT FOR BUILDING "C"

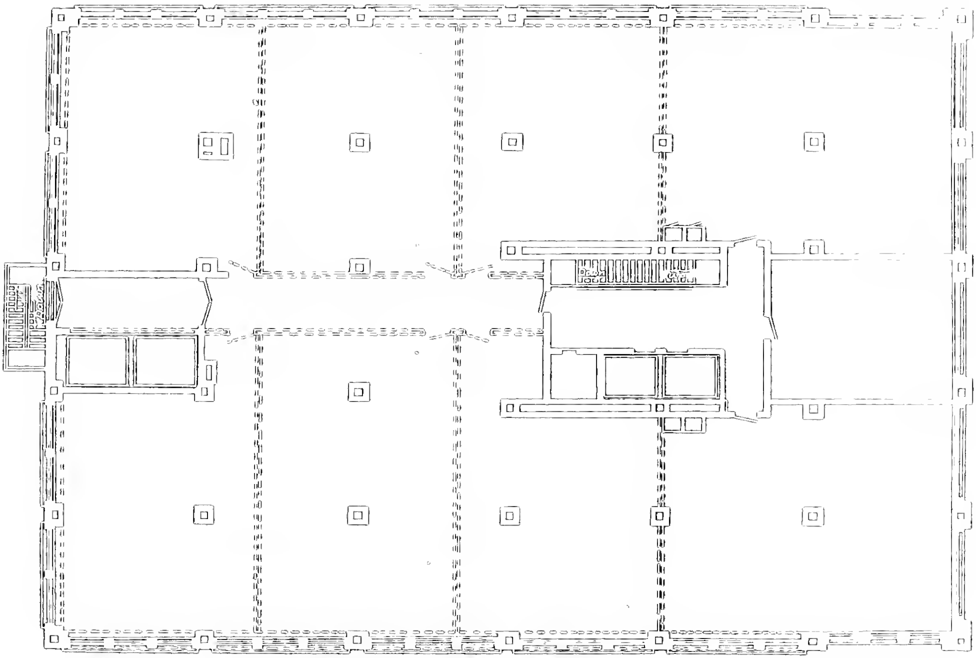

ELEVATION
DESIGN
OF
POWER PLANT
FOR
BUILDING 'C'


BOILERSETTING.
DESIGN
OF
POWER PLANT
FOR
BUILDING 'C'
Scale $\frac{1}{4}$" = 1 Foot.
P.E.H.



FLOOR PLAN OF BUILDING "A"

Figure 4.



0 5 10 15 20 Feet
SCALE

FLOOR PLAN OF BUILDING 'B'

Figure 5.

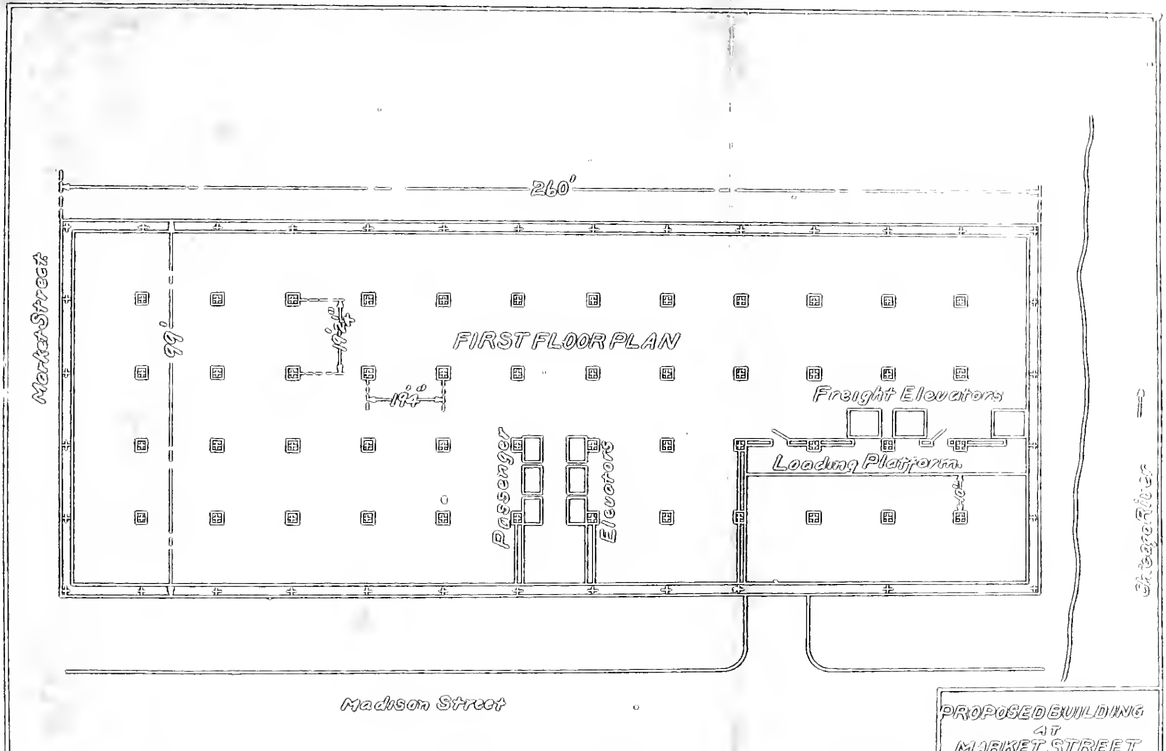

260'
Market Street
99'
FIRST FLOOR PLAN
19'4"
Freight Elevators
Passenger
Elevators
Loading Platform.
Chicago River
Madison Street
PROPOSED BUILDING
AT
MARKET STREET
Dec. 24, 1909.

Figure 6.

GENERAL DATA

	Bldg. "A"	Bldg. "B"	Bldg. "C"
Floor Space			
Length	100.75'	111.28'	257'
Width	44.8'	75.67'	96'
Area in Sq. Ft.	4502.6	8420.6	24672
Stories	14	12	14
Height of - Average	11'	11.5'	10'
Glass Surface in Sq. Ft.			
North Exposure	3349	6321	16435
West "	5143	5174	7350
South "	3369	9177	16170
East "	4600	3929	7525
Wall Exposure exclusive of glass in sq. ft.			
North Exposure	3572.6	8979	20316
West "	10422.8	5230	6378
South "	3552.6	6123	20561
East "	10965.8	6475	6203
Total Wall Exposure Glass Equivalent in Sq. Ft.	20535	28572	55473
Cubic Feet of Air in Building	748682	1372804	4234208
Type of Heating System	Steam Vacuum	Steam Vacuum	Steam Vacuum
Radiation in Sq. Ft.	5062	7042	13672

Determination of Radiating Surface for Heating.

The overall dimensions of the buildings were taken, thus giving the total area in square feet of the walls. From the area of each wall was deducted the area of all the openings in the wall, the openings being considered as glass. These areas are all noted according to their exposure; as North, South, East and West walls. The radiating surface was determined from these areas by means of a formula by Professor Carpenter, and is as follows:

Building "A"

Exposed Area In Glass Equivalent.

North Glass - - - - - - - -	3349	Sq. Ft.
West " - - - - - - - -	5143	" "
South " - - - - - - - -	3369	" "
East " - - - - - - - -	4600	" "
Sky Ligh " - - - - - - - -	234	" "
Tota - - - - - - -	16695	

North Wall - - - - - - -	3572.6	Sq. Ft.
West " - - - - - - -	10422.8	" "
South " - - - - - - -	3552.6	" "
East " - - - - - - -	10965.8	" "
Total - - - - -	28513.8	

Total Glass - - - - - - - -	16695	Sq. Ft.
10% N. " - - - - - - - -	335	" "
10% W. " - - - - - - - -	514	" "
10% Total Wall Glass Equivalent	2851	" "
10% N. " " "	36	" "
10% W. " " "	104	" "
Total - - - - -	20535	

Building "B"

Exposed Area In Glass Equivalent.

North glass	6321	Sq. Ft.
West "	5174	" "
South "	9177	" "
East "	3929	" "
Total	24601	

North Wall	8979	Sq. Ft.
West "	5230	" "
South "	6123	" "
East "	6475	" "
Total	26807	

Total Glass	24601	Sq. Ft.
10% N. "	632	" "
10% W. "	517	" "
10% Total Wall glass Equivalent	2680	" "
10% N. " " "	90	" "
10% W. " " "	52	" "
Total	28572	

Building "C"

Exposed Area In Glass Equivalent.

North Glass - - - - - - -	16435	Sq. Ft.
West " - - - - - - -	7350	" "
South " - - - - - - -	16170	" "
East " - - - - - - -	7525	" "
Total - - - - - -	47480	

North Wall - - - - - - -	20316	Sq. Ft.
West " - - - - - - -	6378	" "
South " - - - - - - -	20581	" "
East " - - - - - - -	6203	" "
Total - - - - - -	53478	

Total Glass - - - - - - -	47480	Sq. Ft.
10% N. " - - - - - - -	1643	" "
10% W. " - - - - - - -	735	" "
10% Total Wall glass Equivalent -	5348	" "
10% N. " " "	203	" "
10% W. " " "	64	" "
Total - - - - - -	55473	

Radiating Surface.

Building "A"

From Carpenter on "Heating and Ventilation" we have the following formula:

$$B\,(t - t_1) = C\,(T - t)R \quad \text{or} \quad R = \frac{B(t - t_1)}{C(T - t)}$$

Where: t_1 = Outside Temperature = 0°
t = Room " = 70°
T = Steam " = 212°
B = Sq. Ft. of exposed area in glass equivalent
R = Radiating Surface in Sq. Ft.
C = Heat Units per Sq. Ft. per degree per hour from radiating surface

$R = \frac{20535(70-0)}{2(212-70)}$ = 5062 Sq.Ft. or 1437450 BTU per hour in zero weather

As the mean cold temperature is about 35° only 1/2 this heat is necessary, or 718725 BTU per hour.

Building "B"

$R = \frac{28572(70-0)}{2(212-70)}$ = 7042 Sq. Ft. or 2,000,000 BTU per hour in zero weat

As the mean cold temperature is about 35° only 1/2 this heat is necessary, or 1,000,000 BTU per houe.

Building "C"

$R = \frac{55473(70-0)}{2(212-70)}$ = 13672 Sq. Ft. or 3883110 BTU per hour in zero weath

As the mean cold temperature is about 35° only 1/2 this heat is necessary, or 1941555 BTU per hour

Additional Heat Necessary Due To Ventilation.

Allowing:- two changes of air per hour. That one BTU will heat 55 cu. ft. one degree. That two BTU are radiated per sq. ft. of radiating surface per degree difference per hour. That the temperature rise is from 35° to 70° F.

Building "A"

Cubic contents of building = 748682 cu. ft.

$$\frac{35 \times 748682 \times 2}{55} = 952868 \text{ BTU}$$

Steam.

BTU supplied per hour (1437450 + 952868) = 2390318
Available heat per pound steam @ 212° = 970 BTU
2390318 ÷ 970 = 2464# steam in zero weather, or 1723# in ordinary weather.

Building "B"

Cubic contents of building = 1372804 cu. ft.

$$\frac{35 \times 1372804 \times 2}{55} = 1747223 \text{ BTU}$$

Steam.

BTU supplied per hour (2,000,000 + 1747223) = 3747263
Available heat per pound steam @ 212° = 970 BTU
3747263 ÷ 970 = 3862# steam in zero weather, or 2832# in ordinary weather.

Building "C"

Cubic contents of building = 4234208 cu. ft.

$$\frac{35 \times 4234208 \times 2}{55} = 5388992 \text{ BTU}$$

Steam.

BTU supplied per hour (3883110 + 5388992) = 9272102
Available heat per pound steam @ 212° = 970 BTU
9272102 ÷ 970 = 9559# steam in zero weather, or 7557# in ordinary weather.

Steam Consumed in Early Morning Heating

Winter Season

In the present day office building the steam is generally in the heating system until nine o'clock in the evening. At this time the building is closed and as the doors and windows are all shut, the temperature of the building will fall quite slowly, and except in extreme cold weather will not be below 50° F. by six o'clock in the morning, at which time live steam is turned into the heating system. Assuming this to be the case it is then necessary to heat a volume of air equal to the cubi contents of the buildings from 50° F. to 70° F. This heating is to be done from six to eight o'clock in the morning with live steam, and will be assumed to be 5° in each half hour; or the rate per hour at which the steam must be supplied will be as follows:

The total cubic contents = 6355694 cu. ft.
Allow one air change per hour
Allow that one B.T.U. will raise the temperature 55 cu. ft. one degree.

Steam required to raise this volume from 50° to 70° is:

$$\frac{2 \times 6355694}{55} \times \frac{20}{970} = 4766\#$$

To raise this volume from 55° to 70° requires:

$$\frac{2 \times 6355694}{55} \times \frac{15}{970} = 3574\#$$

To raise this volume from 60° to 70° requires:

$$\frac{2 \times 6355694}{55} \times \frac{10}{970} = 2383\#$$

To raise the volume from 65° to 70° requires:

$$\frac{2 \times 6355694}{55} \times \frac{5}{970} = 1192\#$$

In the [illegible]

the heating [illegible]. At [illegible]
the building is closed and [illegible],
the temperature of the building [illegible]
in extreme cold [illegible]
the morning, [illegible]
system. Assuming [illegible]
a volume of air [illegible]
50° F. to 70° F. [illegible]
o'clock [illegible]
5° in [illegible]
be assigned [illegible] follows:

The total [illegible] ft.
Allow one [illegible]
Allow [illegible] ft.,
one degree.

Steam [illegible]

2 x 65 [illegible]

To raise this [illegible]:

[illegible]

To raise the volume from [illegible]:

[illegible]

To raise the volume from [illegible]:

[illegible]

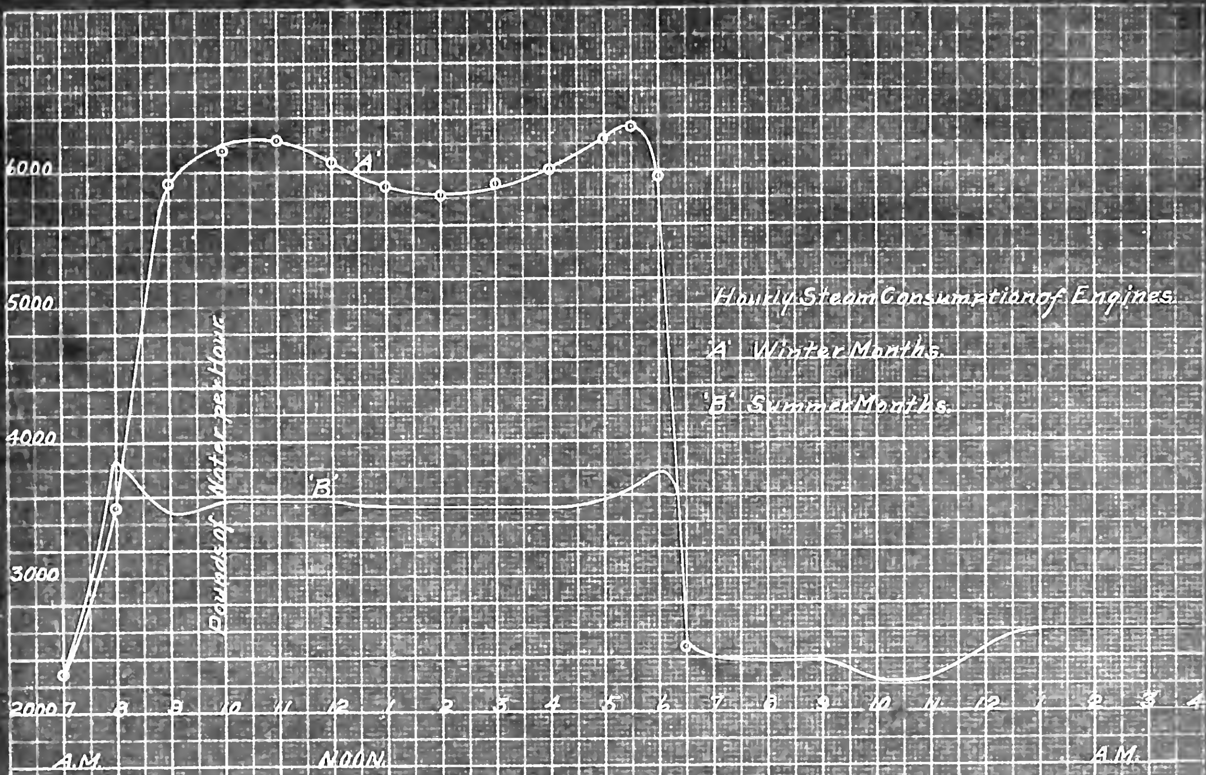
HOURLY STEAM CONSUMPTION FROM DAILY LOAD CURVES.
Summer Season.

Time	Unit	H.P.	% Full Load	Steam per H.P. Hour	Steam per Hour
5-7 AM	1	75	60	30.8	2310
8	3	225	53	17.2	3880
9	3	225	93	15.5	3490
10	3	225	106	15.8	3560
11	3	225	106	15.8	3560
12	3	225	106	15.8	3560
1 Noon	3	225	100	15.7	3530
2 PM	3	225	100	15.7	3530
3	3	225	100	15.7	3530
4	3	225	100	15.7	3530
5	3	225	106	15.8	3560
6	3	225	127	16.8	3780
6:30	2	150	130	16.5	2480
7	2	150	100	16	2400
8	2	150	80	15.9	2380
9	2	150	80	15.9	2380
10	1	75	120	29.8	2240
11	1	75	70	30.1	2260
12 MN	1	75	40	32.8	2460
1-5 AM	1	75	30	34.8	2610

HOURLY STEAM CONSUMPTION FROM DAILY LOAD CURVES.
Winter Season

Time	Unit	H.P.	% Full Load	Steam per H.P.Hour	Steam per Hour	
5-7AM	1	75	60	30.8	2310	
8	3	225	73.5	16.0	3540	
9	3	225	100	15.7	3530	5930
	2	150	100	16.0	2400	
10	3	225	120	16.5	3720	6160
	2	150	120	16.3	2440	
11	3	225	127	16.8	3780	6240
	2	150	127	16.4	2460	
12 Noon	3	225	116	16.2	3640	6070
	2	150	116	16.2	2430	
1 PM	3	225	96	15.6	3510	5910
	2	150	96	16.0	2400	
2	3	225	92	15.4	3460	5840
	2	150	92	15.9	2380	
3	3	225	98	15.6	3510	5910
	2	150	98	16.0	2400	
4	3	225	110	16.0	3600	6020
	2	150	110	16.1	2420	
5	3	225	127	16.8	3780	6240
	2	150	127	16.4	2460	
5:30	3	225	136	17.0	3830	6320
	2	150	136	16.6	2490	
6	3	225	88	15.5	3490	5970
	2	150	88	15.9	2390	
6:30	2	150	130	16.5	2480	

6:30 PM to 5:00 AM - - Conditions as for Summer load.


Hourly Steam Consumption of Engines.
'A' Winter Months.
'B' Summer Months.
Pounds of Water per Hour.
6000
5000
4000
3000
2000
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
A.M.
NOON.
A.M.
'A'
'B'
Figure 7.

Size of Pipe to Carry Steam to Buildings "A" and "B".

From Kent we have the following formula:

$$Q = 60 \times .7854 \times 50\ D^2 \left\{\frac{144\ (p_1 - p_2)\ D}{WL}\right\}^{1/2}$$

Where: p_1 = initial pressure of steam
p_2 = final " of steam
W = weight per cu. ft. of steam at p_2
D = diameter of pipe in feet
L = length of pipe in feet
Q = quantity of steam flowing per minute in cu. ft.

Weight of steam necessary 6326# per hour = 2775 cu. ft. per minute.

$$2775 = 2356\ D^{5/2} \left(\frac{144\ (25\ 15)}{.0614 \times 1162}\right)^{1/2}$$

$$D^{5/2} = \frac{2775}{10555} \text{ or } D^5 = \frac{\quad 2}{.2629}$$

$$D = .5860 \text{ ft.} = 7"$$

Computation based on needs of the most severe weather.

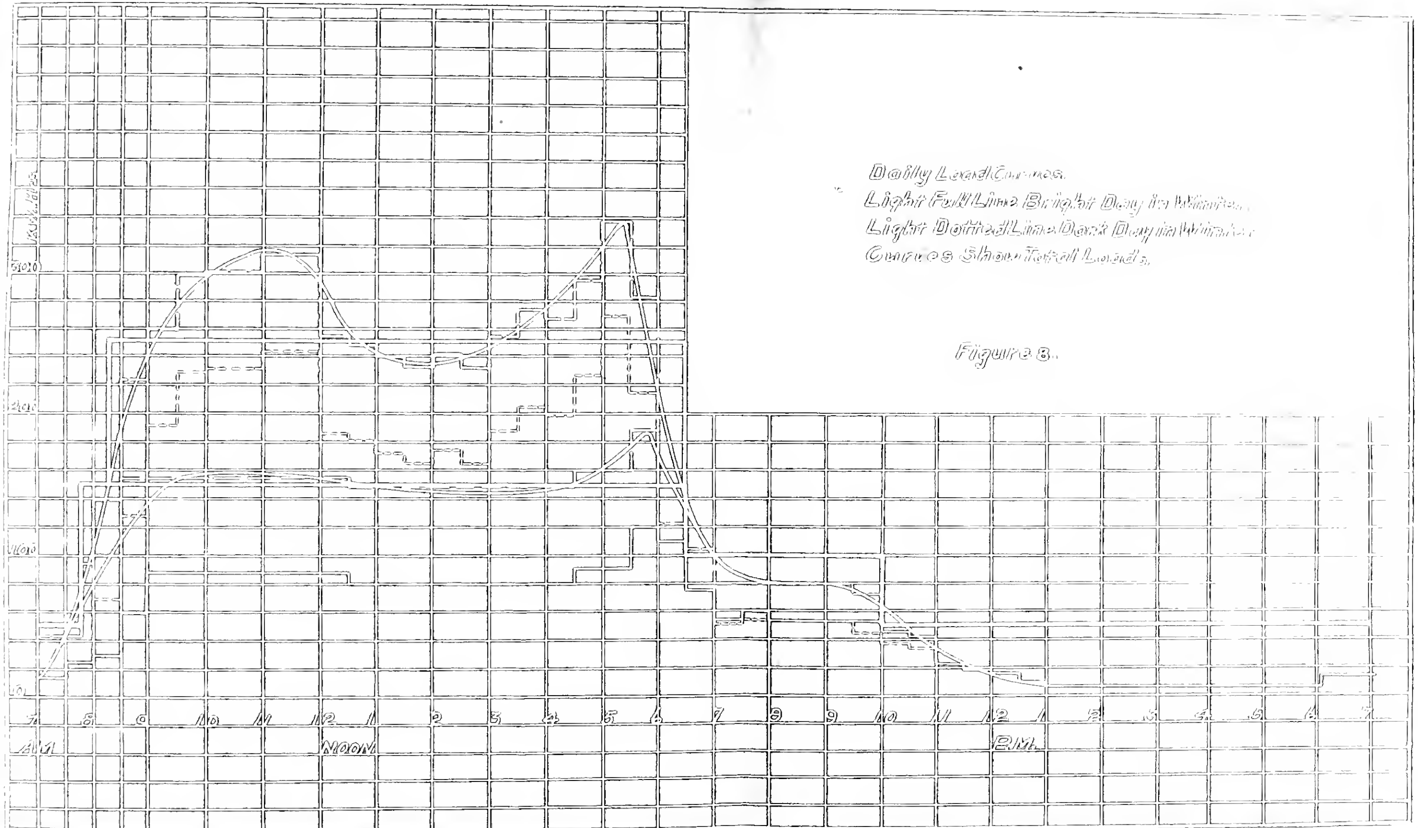

Daily Load Curves.
Light Full Line Bright Day in Winter.
Light Dotted Line Dark Day in Winter.
Curves Show Total Loads.
K.W. Hrs.
3000
2000
1000
A.M.
NOON
P.M.

Figure 8.

Size Of Electrical Units.

In this determination two load curves, one for a bright day and one for a dark, foggy day, both in winter time, were obtained from an office building where conditions were similar to these to be considered. The ordinates of these curves were effected by the ratio of the rentable floor area of the building to which the curves applied, to the rentable floor area of the building under consideration. This gives two loads; they are for the lighting only, and to each was added the power necessary to operate the elevators. The two curves thus constructed are assumed to be maximum daily conditions for summer and winter months.

From these curves of maximum conditions the electrical units were determined and arranged to carry the load the most economically.

Unit #1	- - - - -	50 K W
" #2	- - - - -	100 K W
" #3	- - - - -	150 K W
" #4	- - - - -	150 K W

Size of Steam Units.

Allow an efficiency of 95% in the electrical units and an efficiency of 90% for the steam units.

1 K W = 1000 Watts
1 H P = 746 "

Therefore $\frac{1000}{746}$ = 1.34 Electrical horsepower

1.34 + 5% = 1.407 Brake horsepower
1.407 + 10% = 1.55 Indicated horsepower

Or roughly add 50% to the rated capacty of the electric unit expressed in kilowatts for the indicated horsepower of the steam unit.

Economy of The Steam Units.

These curves of engine economy are deductions from similar curves taken from "The Economy Factors in Steam Power Plants" by Geo. W. Hawkins.

Hourly Steam Consumption.

The curves of hourly steam consumption were plotted from the load curves and engine economy curves, i.e., for each hour of day from the load curve was taken the per cent. of full load at which the units were operating. With this percentage from the economy curve is found the water rate of the particular steam unit. These values multiplied by the horsepower of the unit gives the steam consumption per hour.

Estimate of the Electrical Current Consumed In Buildings "A", "B" & "C".

Lighting for Tenants -

This estimate is computed on the basis of the rented floor area. The data was obtained on a typical office building; one which furnished its tenants with electrical current for lighting.

The actual current consumed by the tentants divided by the total area of rentable floor space gives the current necessary for lighting per sq. foot.

Lighting for Halls -

The total area of floor space less the rented area is considered as halls; and as above the current used for lighting this area divided by the area gives the current necessary for lighting per sq. foot of halls.

Current for Elevators -

The current consumed in Buildings "A" and "B" is known, the meter readings having been obtained from the engineer in charge. The current for Building "C" was estimated from that consumed in Building "A", the method used being that for estimating the lighting.

Estimate Of Electric Current Consumed Per Year.

Building	For Tenant s Light & Power	House
"A"		
47275 sq.ft. @ 733 Watts sq.ft.	34653 KW Hrs.	
15764 " " "1520 " " "		23961 KW Hrs.
"B"		
88926 sq.ft.@ 733 Watts sq.ft.	65183 KW Hrs.	
12126 " " "" 1520 " " "		18432 KW Hrs.
"C"		
259056 sq.ft.@ 733 Watts sq.ft.	189888 KW Hrs	
86352 " " " 1520 " " "		131255 KW Hrs.
For Motor lcad:		
259056 sq. ft.@ 500 Watts " "	129525	
"A"		
Current to Elevators actual		58032
House and Bilge pump "		3849
"B"		
Current to Elevators actual		35287
House and Bilge pumps "		1727
"C"		
Current to Elevators Estimate		
259056 sq. ft. @ 396 Watts per sq. ft.		102586
House and Bilge pumps		
259056 sq. ft. @ 19.4 Watts per sq. ft.		50257
	419249	425386
Total to be generated		844635 KW Hrs.

Data On Elevators.

Bldg.	No. in Oper- ation	Start- ing Time	Stop- ping Time	Hours per Day	Time for Single Trip	Trips per Day	Single Trips per year	Current consump- tion per year	Current consump tion per trip
									Watts
"A"	1	7:00AM	10PM	15	50"	1080)	466800)		
	2	7:45AM	6 PM	20.5	50"	1476)		)58032 KW	119.5
Sunday only	1	9:00AM	1 PM	4	50"	288	18720)		
							485520		
"B"	1	7:00AM	10PM	15	35"	1543)	777900)		
	1	7:45AM	6PM	10.25	35"	1054)			
Sunday only	1	7:00AM	1PM	6	35"	603	39193)	35287 KW	43.2
							817095		

Estimate of Cost of Power Plant Equipment.

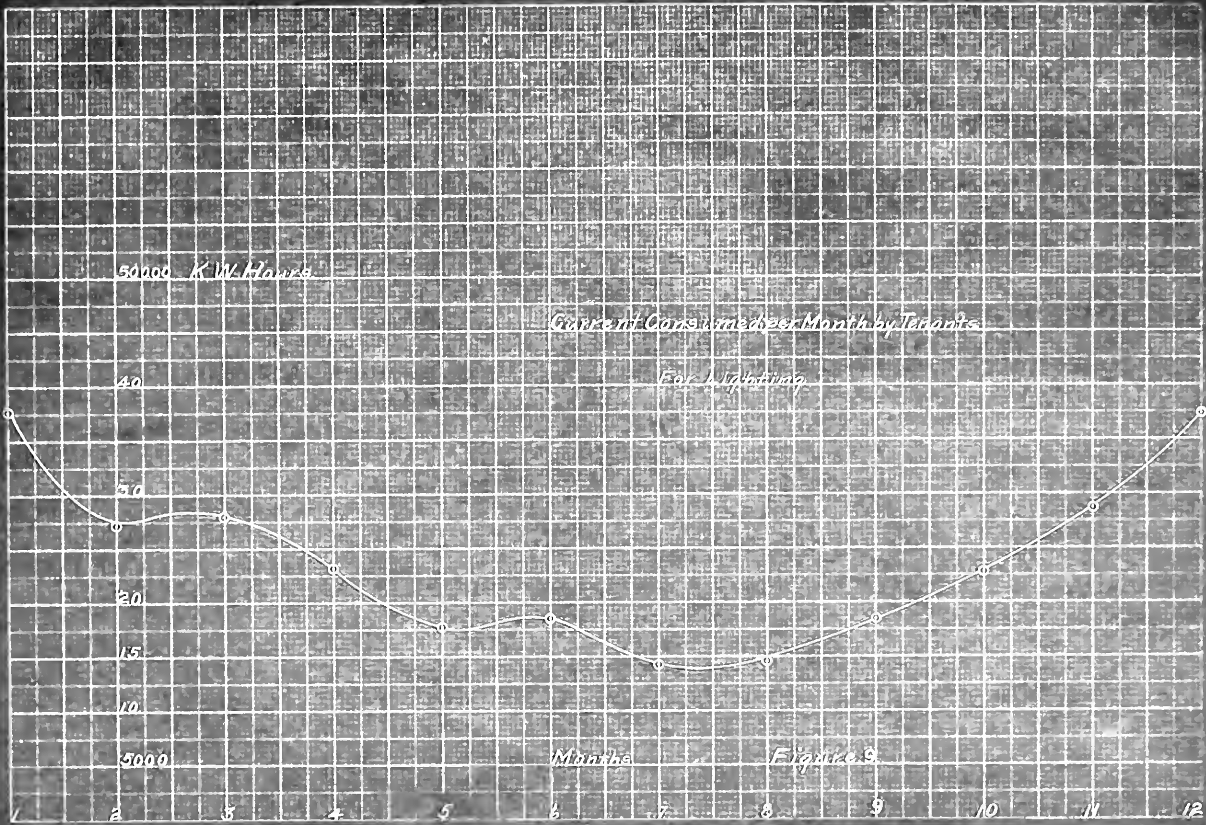
4 - 250 H.P. water tube boilers, sectional header, in place		11000.00
4 - chain grate stokers each 7 ft. x 9 ft. = 63 sq. ft. with two engines, shafting, pulleys, etc., in place - -		3780.00
Boiler foundations - - - - - - - - - - - - - - - - -		1000.00
Boiler settings - - - - - - - - - - - - - - - - - -		3000.00
Coal and ash conveyer and bunkers in place - - - - - - -		
Conveyer 272 ft. @ $20.00 - -	$5440.00	
Driver - - - - - - - - - -	400.00	
4 green coal pans and valves -	176.00	
4 coal bunkers - - - - - - -	2000.00	7976.00
Chimney, steel lined 72" x 200 ft. - - - - - - - - - -		4200.00
Breeching - - - - - - - - - - - - - - - - - - -		800.00
Heater -		600.00
2 feed pumps - ram pattern - - - - - - - - - - - -		750.00

Engines and generators, horizontal high speed direct connected to 220 volt d. c. Generators:

1 - 75 H.P simple Engine - -	-1130.00	
1 - 50 K W generator - - - -	1000.00	
1 - 150 H.P. compound engine -	2100.00	
1 - 100 K W generator - - - -	1500.00	
2 - 225 H.P. Compound engines -	5500.00	
2 - 150 K W generator - - - -	5000.00	16230.00
1 surface condenser with vacuum pump and circulating pump		1200.00
Piping, steam, exhaust and water, in place - - - - - -		4000.00
Miscellaneous and engineering 10% - - - - - - -		5454.00
		$ 59990.00
	Or say	60000.00

Cost per K W $ 133.00
Cost per boiler H.P. 60.00

Note: The above estimated cost p. KW. is not unreasonable as about one-half of the boiler plant investment (or about $14,000.) is required for heating, making the cost of the electric plant $46,000. or $102.00 per KW.


50000 K.W. Hours
Current Consumed per Month by Tenants
For Lighting
40
30
20
15
10
5000
Months
Figure 9
1
2
3
4
5
6
7
8
9
10
11
12

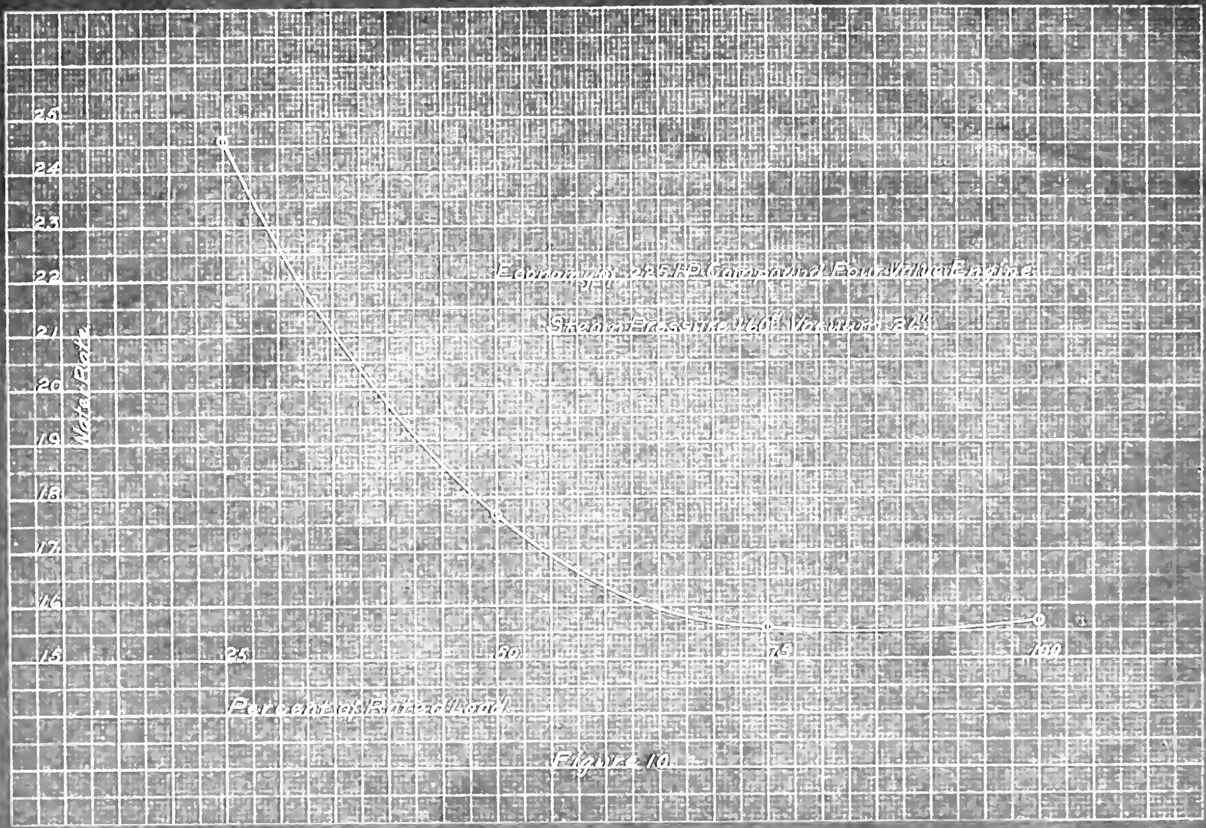

Economy of 225 H.P. Compound Four Valve Engine.
Water Rate
25
24
23
22
21
20
19
18
17
16
15
25
50
75
100
Percent of Rated Load

Figure 10

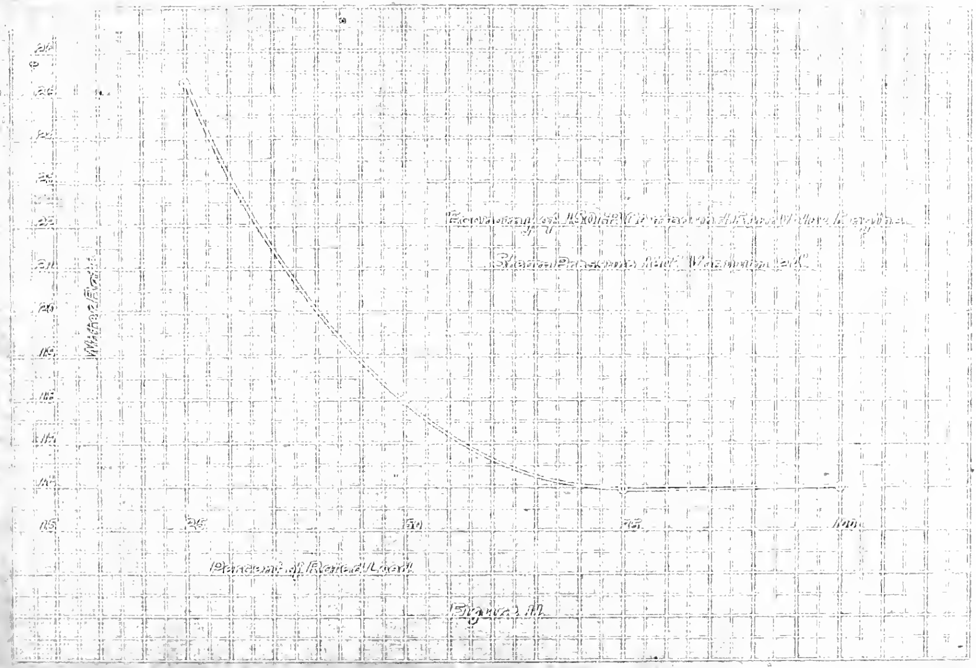


Figure 11.

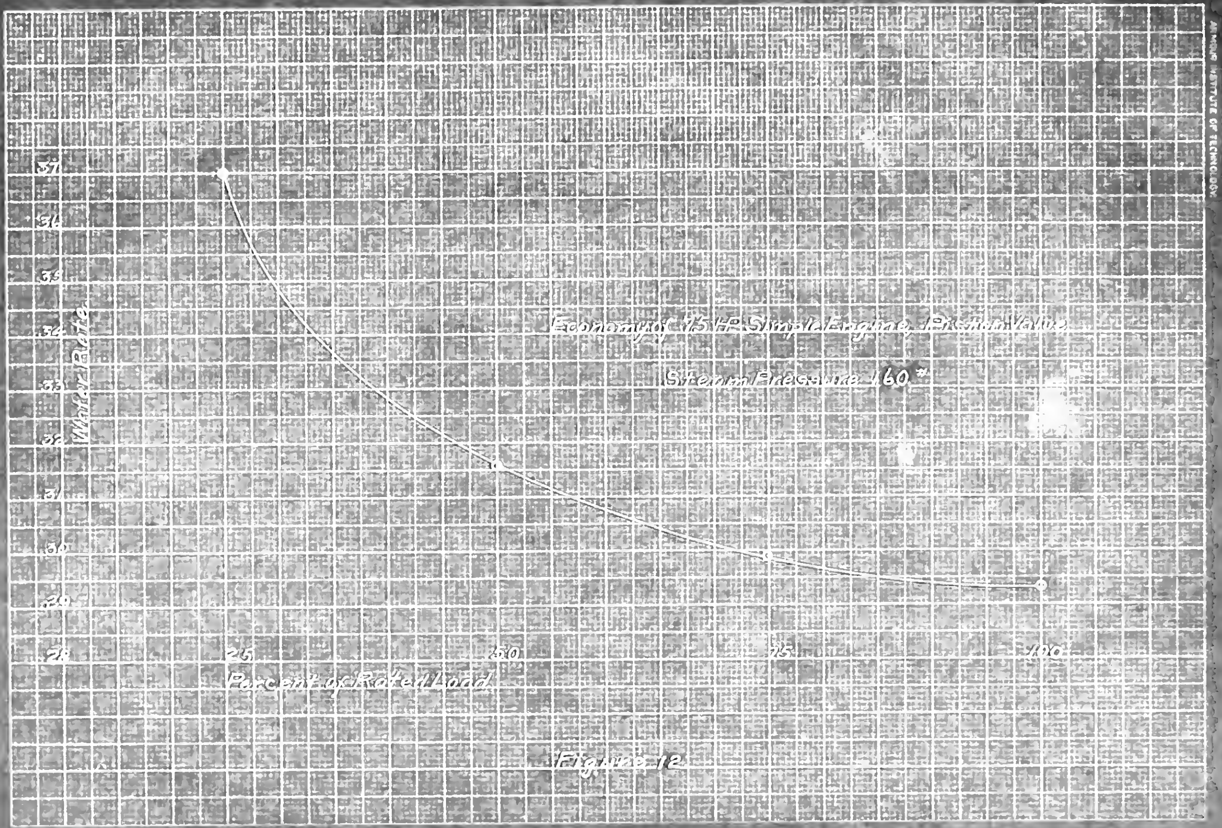
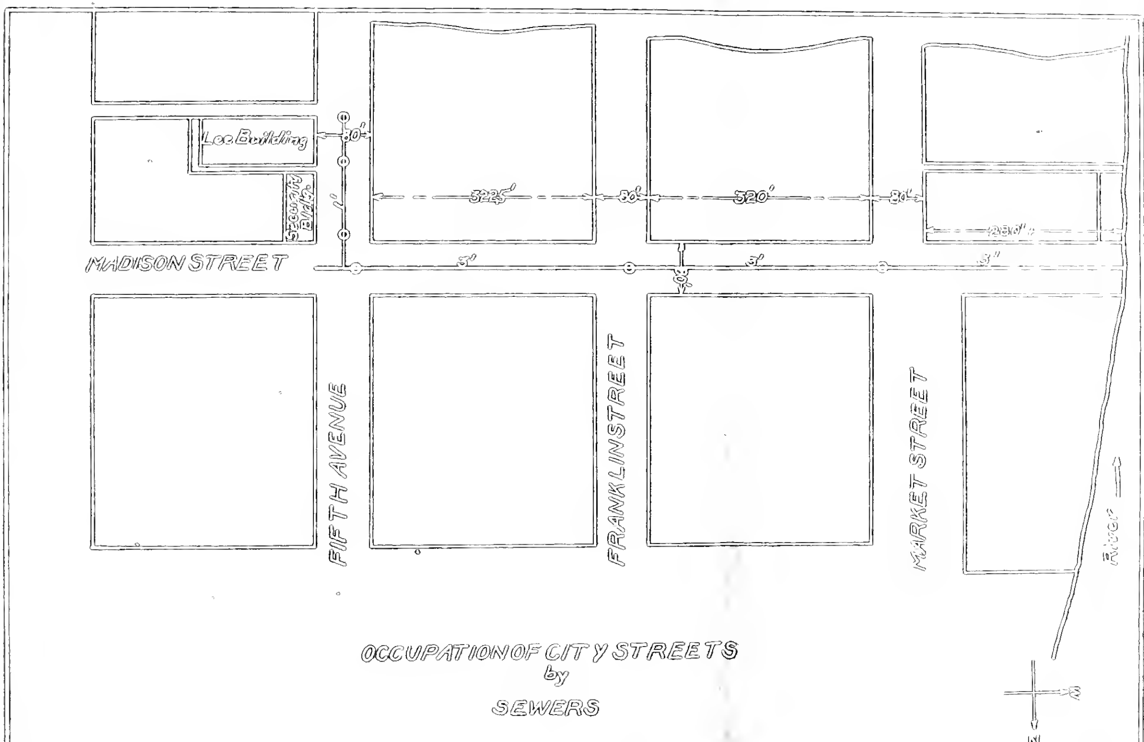
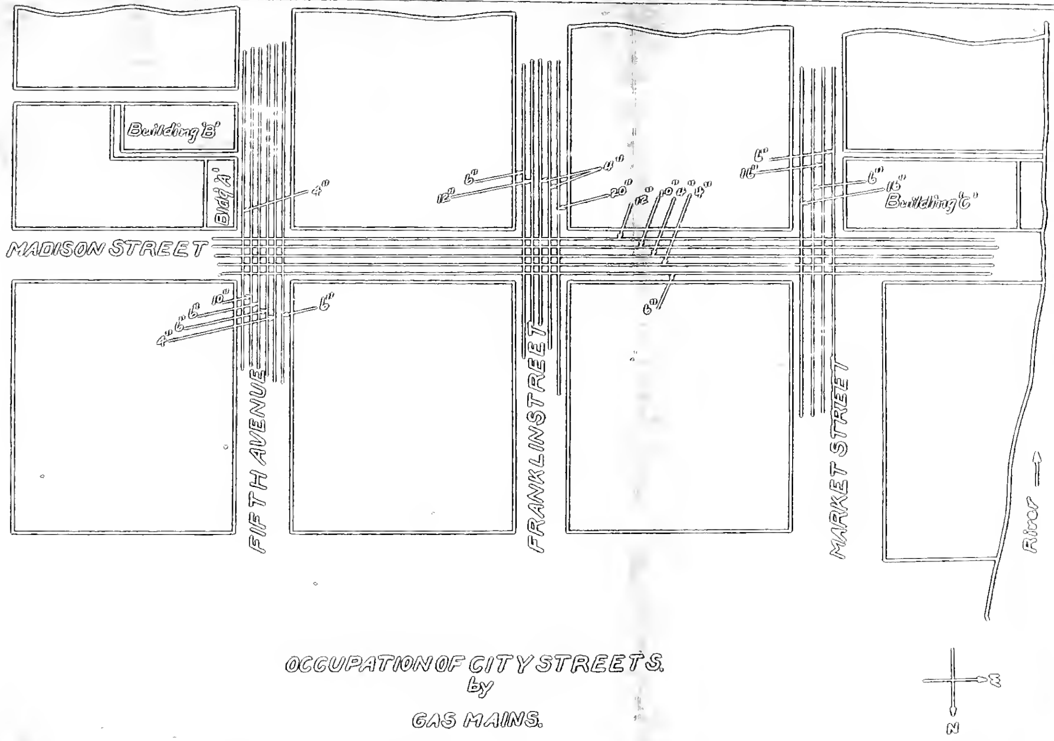

ARMOUR INSTITUTE OF TECHNOLOGY
Economy of 75 HP Simple Engine, Piston Valve
Steam Pressure 160 #
Water Rate
37
36
35
34
33
32
31
30
29
28
25
50
75
100
Percent of Rated Load

Figure 12



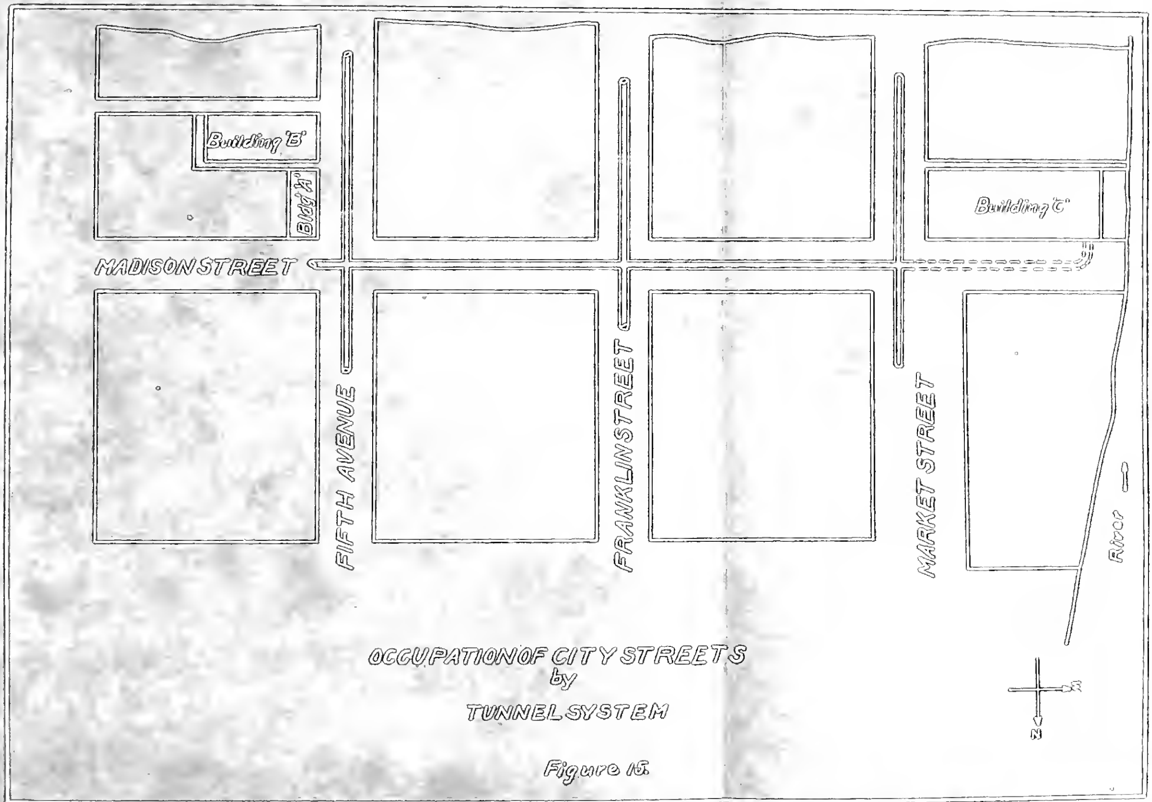
OCCUPATION OF CITY STREETS
by
SEWERS

Figure 13.



OCCUPATION OF CITY STREETS.
by
GAS MAINS.

Figure 14.



OCCUPATION OF CITY STREETS
by
TUNNEL SYSTEM

Figure 15.